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ATI-

REPORT ON FULL SCALE PULSE JET TESTING

Compiled by

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Technical Memorandum NYU-12

P R O J E C T   S Q U I D

A Cooperative Program
Of Fundamental Combustion Research
As Related to Jet Propulsion
For the
Office of Naval Research, Department of the Navy
Research and Development Command, Department of the Air Force
Contract N6ori-11, Task Order II
NR 220-040, Phase 3

REPORT ON FULL SCALE PULSE JET TESTING

by

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November 7, 1951

This report covers the work done by New York University on full scale pulse jet engines during the period 1 June 1947 to 30 September 1949. It was originally planned that a comprehensive program of investigation would be undertaken to gather sufficient data on the operation of a full scale pulse jet engine to permit evaluation of certain combustion parameters for use in the mathematical theory of pulse jet engines[1] developed by the late Dr. J. K. L. MacDonald, then Technical Director of the N.Y.U. Squid Project.

1. "A Gas Dynamical Formulation for Waves and Combustion in Pulse Jets, AMG-NYU Report No. 151, June 1946.

Spring and Summer 1947

Inquiries were made to the Office of Naval Research concerning the availability of the Navy equivalent of the Army JB-2 pilotless aircraft, which is an improved version of the the German Verteilungswaffe Eina (V-1). At that time, there were no Navy units available for such assignment. Arrangements were made to obtain an Army JB-2 for this work. This equipment arrived late in 1946 and was stored until arrangements for a test site were completed. Negotiations with Reaction Motors, Inc., Dover, New Jersey, were completed April 1947 to provide a suitable test site and necessary service equipment. Early in June 1947, the JB-2 was trucked out to Reaction Motors and set up. As described in the Army Air Force Technical Order describing the use of the JB-2, the engine was set up on a crate base for ground running. To prevent the accumulation of fuel in the combustion chamber, the whole assembly was raised at the forward end. Facilities available were 110 volt AC power to operate engine electrical equipment and photographic equipment, and compressed air at 200 psi for purging the burned gases and operating the engine pneumatic equipment.

A-1

The engine was operated from a control board located approximately 20 feet from the valve and engine to avoid exposing the operator to any unnecessary hazards. On the board were located two switches and one valve. One switch controlled the Ford spark coil and supplied the spark plug used in starting the engine. The valve controlled the compressed air used to operate the pneumatic solenoid to start the fuel flow and also to provide an initial air flow in the engine. The sequence of operations were: (1) Turn on the spark coil, (2) Turn on the compressed air until engine started, (3) Turn off the compressed air at the spark, (4) Let the engine run 10 to 20 seconds, (5) Operate the fuel cut off solenoid to stop the engine, (6) In the event of failure of the fuel cut off solenoid to operate effectively, the hand-operated valve could be activated with a rope. After familiarization runs, it was decided that the most easily obtainable data were the records of the flame motion inside the engine, these to be obtained by means of a streak camera. A series of ¼" holes spaced 6" apart were drilled along the longitudinal axis of the engine. It was soon found even in night operations that exposure densities were insufficient. Above each of the ¼" holes, a second ¼" hole was drilled and quartz windosw were designed to cover both holes. This window construction work involved delay for many weeks, as the quartz windows had to be obtained, polished, and frames fitted for each of them.

Figure 1 shows flame motions which were obtained with the streak camera. In the left hand photograph is shown the relative valve positions. This was obtained by placing the mirror upstream from the valves. Figure 1A was obtained with the ¼" holes uncovered. Figure 1B shows the flame motions under steady normal operating conditions with the holes covered with pyrex glass windows. The valve motions were obtained by placing the mirror upstream from the valve banks and placing an automobile headlight 30 feet downstream from the tail but directed along the jet axis. Both Figures A and B illustrate the fact that the initial explosion is not completely blown out the tailpipe on the first cycle but leaves the tailpipe by the second cycle. The exhaust flames shown in Figure A and B were photographed through a slit placed between the camera and the jet engine.

The tailpipe flames were observed at night with an Eastman high speed camera run at approximately 720 frames/second. These photos are shown in Figure 2. The windows were open when these photos were taken. They again show clearly the continuous burning within the tailpipe. The indications of the beginning of vortex action observable in these pictures have been investigated further in cold pulse studies.[2]

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2. Project Squid Quarterly Progress Report, 1 July 1949, Page 5
   Project Squid Quarterly Progress Report, 1 Oct. 1949, Page 7

Attempts were made to investigate the flow of gases in the tailpipe by the use of smoke generators, but this attempt was not successful photographically because of the low smoke density.

This work indicated the desirability of making many modifications in the equipment. Since the test site arrangements were not mutually satisfactory, the agreement with Reaction Motors, Inc. was terminated on August 1, 1947, and the equipment returned to N.Y.U. Two major modifications were planned in the equipment: (1) Modification of the engine controls for easier starting and smoother operation, (2) The construction of several units of associated equipment to provide a completely mobile set of testing equipment. It was felt that if each major item of equipment was easily transportable, there would be fewer delays in the field operations.

Engine Modifications

The details of the modifications made in the engine controls were based on practices developed at USNAMTC, Point Mugu, California. The following changes were made. The starting air was separated from the fuel meter air. This separation was accomplished by establishing a new input line to the starting air manifold and a separate pipe line to the starting air system at the engine grill. This modification permits a preloading of air in the combustion chamber. It also permits purging of the combustion chamber by remote control through the starting air jets. The preloading of the combustion chamber forces smoke and gasoline fumes out of the area and allows a correct mixture for starting. A schematic of this new arrangement is shown in Figure 3.

In addition to the changes in the fuel metering system shown in Figure 3, the whole operation of this engine has been modified so that it can be handled remotely with solenoid valves through a 24-volt DC circuit. The pressure system is split into two sections as described in the foregoing paragraph, and each section has a solenoid remotely controlled valve as shown in Figure 4. In order to operate this new system remotely, a motor-generator set and battery were provided to give a 24-volt power source and a remote control panel was constructed as a central switch station.

All the circuits on the mobile thrust stand, Figure 5 are conducted through a conjunction box, which is shown as No. 17 on Figure 5. The solenoid valves and spark coil are mounted on the internal control board, the location of which is shown as No. 19 in Figure 5.

In summary of Section 1, the modifications which have been made in the operating system of this engine have been keyed to ground test operation, although with slight changes of location they may be very easily applied to launching problems.

It was felt that this set-up would increase the safety of operation by removing all personnel, with the possible exception of one fire guard, from the immediate vicinity of the jet. It would also permit operation of the equipment in inclement weather by placing the control panel under shelter.

Thrust Stand

The multiple problem of providing a suitable stand to support the engine during tests and to arrange for some way of making any necessary engine modification without building an elaborate field station, was solved by using the large surplus radar trailer to carry the JB-2. It was felt that by doing this, it would be possible to avoid extensive field construction work and to bring the trailer back to this laboratory whenever any extensive work was required.

Since the engine stand had to be constructed on the trailer, it was decided to construct this in such a manner that the thrust measurements could be easily taken, as soon as the program required such measurements. A design involving a parallelogram hanging on A-frames was finally used as illustrated in Figure 5. This construction work was completed early in 1948.

Power Trailer

The need for 110 volt, 60 cycle electrical power to operate the recording instruments was filled by using the power trailer that came with the surplus radar set which furnished the thrust stand trailer. The power trailer had a van body containing 25 KVA 110 v. 60 cycle motor generator set which was driven by a gasoline engine. This set contained automatic governors which yielded fair frequency stabilization.

Prime Mover and Field Workshop

To tow either the bomb trailer which weighed 5 tons, or the power trailer which weighed 8 tons, a large truck with compressed air brakes was required. A White 6 x 6 rated at 12 tons was used. This truck came as part of a second surplus radar set and had in its van body a motor generator set similar to that in the power trailer. As this was not needed it was moved, and the body converted into a workshop. A large crane boom was constructed for attachment to the front of the truck to make it possible to rig the bomb into position in the thrust stand or to remove the engine for maintenance. This crane was carried on the roof of the truck when not in use. A 200 lb. air compressor driven by a gasoline engine was mounted in the truck body to deliver compressed air for starting the PJ-31 engine.

Observation Equipment

From the end of March 1947 until the beginning of July 1948, the Mobile Air Blast Laboratory of the Woods Hole Oceanographic Institute was available for use on this contract. Early in 1948, however, as the field equipment was being set up at the Rye test area, word was received that the Woods Hole unit would be needed at the Naval Ordnance Laboratory in the late Spring or early Summer. Steps were therefore immediately taken to provide a replacement so that work on the field test would not be interrupted by the lack of recording equipment. Since no other unit of this type was known to this group, it was felt that in view of future usefulness of a unit of this type to the Government on any investigations requiring field tests, the possibility of constructing a similar unit should be investigated. It was found that still another of the surplus trailers could be converted into a van type at a price well below the cost of constructing an observation shack for the field work and that the necessary recording equipment would essentially be that required for recording the temperature and pressure signals from a number of stations on the PJ-31.

As a result of these considerations, a 22' full trailer was modified to provide the following facilities:

1. An observation section from which the engine could be controlled and photographed,
2. A recording equipment section in which all the electronic gear for pressure, temperature and miscellaneous instrumentation could be installed and controlled,
3. A small photographic dark room in which the resulting records and motion picture film could be developed as required.

A more complete description of this unit will be found in Appendix III.

Rye Test Site

In September 1947 negotiations were begun with the officers of the Westchester County Airport Corporation for rental of land for a test site at the Westchester County Airport. With the assistance of the cognizant ONR Branch Office, a suitable contract to cover the cost of renting space for a period of six months was negotiated, after careful consideration of the additional costs of preparing the site for our use.

The location selected was in an unused corner of the airport well away from the airport buildings and as far as possible from the nearest habitation. A rough dirt road was graded to the site and a suitable area 100' x 100' graded therein. This was surfaced with several loads of cinder and the test area was ready for use in January 1948. This site was used until September 1948 when the Corporation completed negotiations for the erection of another airport hangar on this ground at which time the NYU test equipment was moved to another area of the field which was suitable for our use.

Work Performed at Rye February 1948 to October 1948

This period was occupied in setting up the equipment solving several major operational problems and gathering some preliminary data with the temperature and pressure systems.

From the latter part of February to the end of March no successful runs were obtained. At this time the valve bank was replaced and a manually operated valve was used in place of the original automatic unit. During the month of April, the conditions for satisfactory engine operation were investigated, and a decibel level survey of the test area was made. It had been hoped that this work would uncover a set of engine operating techniques that would ensure a successful run each time the engine was started, but unfortunately as the work progressed the frequency of successful starts actually decreased until a point was reached at which attempts to gether data became fruitless. After careful study of the results obtained, it was concluded that both this and the previous difficulty with engine starting was due to the gradual increase in the valve leaf stiffness over a period of time. Though the actual running time was well below an hour at this point the frequent false starts caused the valve leaves to be heated many times to a much higher temperature than encountered in flight which seemed to cause a progressive deterioration of the valve action which is marginal at best during a static start. Since valve grills were not available as a separate part because the JB-2 was designed for single use before destruction, it was necessary to attempt to retemper the valve leaves on a used valve grill. This work took much longer than expected since special shaping dies had to be constructed to hold the leaves during retempering and was not completed until the beginning of September 1948.

Work Performed at Rye October 1948- October 1949

During this time the work at Rye was given a much lower priority than during the previous year, and only 5 percent of the applicable phase assignment funds were allocated for this work due to the decline of sponsor interest in this type of engine. It was hoped that the difficulties encountered during the previous year would be the last and that it would be possible to gather a great deal of useful data during the course of developing the pressure and temperature systems being studied by this group. It was found, however, that the engine operating difficulties were not completely solved even after the manual valve was replaced by a remote control valve and an automatic sequence timer installed in place of the manual control board. The frequency of successful starts remained very low and the amount of data gathered was correspondingly low until May when the mobile blower was moved to Rye to provide ram air[3]. The air was fed from the Merlin supercharger through a 6" flexible hose

3. "A Mobile High Capacity Blower Unit", M.W. Woody and Daniel Kasner, Tech. Memo. NYU-5 Nov. 1948.

to a point 4" upstream from the valve bank of the JB-2. For normal starts the Merlin was first brought up to at least 2/3 throttle and then the automatic starting sequence of the JB-2 took over. Usually the Merlin was shut down as soon as the JB-2 started.

Pressure Records

The pressure records were taken at various times at 3 points along the axis as shown in Photo No. 6. The gauges used were NYU pickups developed from the gauge described in the literature[4]. The distances of the three gauges from the

4. "A Frequency Modulation Pressure Recording System", Rev. Sci. Instr., Vol. 21 #2, 150 Feb. 1950.

valve bank were $10\frac{1}{2}$", 64" (beginning of tailpipe), 130", end of tailpipe.

Figure 7 shows some of the records obtained at these various positions. On each film strip are two pressure records, (A) being a gauge maintained in the combustion chamber as a reference element while (B) is a gauge moved to various positions on the engine. This arrangement was adopted since the engine operating conditions were not always reproducible. The pressure calibration is indicated on each record.

Record No. 1 shows the gauges in the combustion chamber and the B gauge at the beginning of the tailpipe. Amplitude + 5 to - 5 psi.

Record No. 2 shows the pressure waveform (B) halfway down the tailpipe. This is very similar to the waveform obtained in the large amplitude piston driven air column built by R. J. Kraushaar.

Record No. 3 gives the results obtained at the end of the tailpipe. The high frequency oscillations are suspected of being a microphonic signal, since nothing similar appears on the other records. Amplitude of upper trace $\pm$ 3 psi, of lower + 5 to - 5 psi.

Any unidentified lines represent other recording traces not used in these runs and have no significance.

The important fact evident from these records is that the pressures at all points are closely in phase indicating that the mass of gas in the engine moves as a unit. This has been actually observed in schlieren motion pictures taken in transparent model jets. The same type of gas motion has been observed in piston driven gas columns used in theoretical analyses of jet operation.

As experiment was performed in an effort to check the pressure measurements in which a bank of manometers was connected to points all along the engine as shown in Figure 7. The results were somewhat surprising since the readings fluctuated considerably and differed considerably between adjacent measurement taps. A check on the manometer using the piston driven air column as a pressure source indicated that the pressure readings are dependent on the size of the connecting aperture as well as the length and diameter of the connecting tubing. This is the subject of a separate report[5].

5. "Manometers in Pulsating Systems", by R. J. Kraushaar, submitted to Princeton August 22, 1951 for publication as a Squid Technical Memorandum.

Temperature Work

The temperature measuring instruments were developed from the pyrometer described by Hett and Gilstein[6]. Three temperature stations were mounted at the same points as the pressure gauges, but at no time were more than two stations operating simultaneously.

6. "Pyrometer for Measurement of Instantaneous Flames", by J. H. Hett and J. B. Gilstein, J.O.S.A., Vol. 39, pp. 909-911, November 1949.

Typical temperature traces taken simultaneously at the combustion chamber and at the end of the tailpipe are shown in Figure 8. Figure 9 shows a temperature trace taken at the combustion chamber and reduced. Peak temperatures at the combustion chamber are of the order of $2400^{\circ}K$. This is considerably higher than the $1720^{\circ}K$ average temperature reported by Air Force Testing[7].

7. "Preliminary Testing of German Robot Bomb Engine", Army Air Forces, Memorandum Report, TSEPL-5-673-55, 18 November 1944

Unfortunately the work came to a halt before it was possible to run the three temperature stations simultaneously with the three pressure stations.

Thermistor Gasoline Flow Meter

A thermistor gasoline flow meter[8] was mounted in the fuel line about

8. Project Squid Annual Progress Report 1 January 1948 Page 25
Project Squid Quarterly Progress Report 1 April 1948 Page 13
Project Squid Semi Annual Progress Report 1 April 1951 Page 158
"The Thermistor as a Flow Meter", R. W. King Squid Memo. (to be published)

2 feet distant from the spray nozzles. Two difficulties were encountered:

a) The signal-noise ratio was low for this type of flow.

b) The system needed compensation for the variable temperature of the gasoline.

A pressure gauge was mounted in the fuel line and this showed that the combustion chamber pressure wave is strongly attenuated as it passes back through the spray nozzles.

The work at Rye was concluded before gauge modifications were finished.

Acknowledgements

This work was started under the direction of the late Dr. J. K. L. MacDonald and concluded under Dr. G. E. Hudson.

C. Ralph Sims and David Longstreet were responsible for the firings.

McIver W. Woody, Daniel Kasner and James Jeffress did much work on the mechanical design and fabrication.

Robert W. Kings, Jr. was responsible for the pressure instrumentation and many design features of the instrument trailer.

J. B. Gilstein was responsible for the temperature work.

Howard Hoyt built most of the instrument trailer.

Mr. Woody also aided in keeping the records and in writing this report.

Appendix I

a) Modification to Fuel Metering System.

As a result of suggestions by Lt. J. M. Simpson U.S.N. of USNAMTC, Pt. Mugu, California, the following changes were made in the fuel system of the PJ-31 engine. The starting air formerly delivered through the same compressed air line as that used to actuate the starting solenoid on the fuel metering unit, was rerouted so that each air line was separately controlled by a solenoid valve. This modification permitted "preloading" of air in the combustion chamber and also permitted purging of the combustion chamber through the starting jets without initiating fuel flow. "Preloading" of the combustion chamber forces out smoke and fumes from the combustion chamber and enhances the possibility of getting a correct mixture for starting. It should be noted that the PJ-31 fuel metering unit is so arranged that as long as pressure is applied to the starting air solenoid, the valve delivers fuel at approximately 6 psi and when the pressure is released, this increases to approximately 14 psi.

b) Arrangements for Remote Control of Engine

The manual fuel cut off was replaced by one tripped by an electric solenoid, so that the engine could be operated from an electrical control board set up at a distance. From the board the spark coil could be started and stopped, the starting air and fuel metering unit air turned on and off., and the fuel cut off solenoid operated. In September 1948, this manual control board was replaced with an automatic sequence controller which could be set to perform all these operations in a strictly reproducible manner. Even though the metering unit was properly calibrated, successful operation was not obtained until the unit was replaced with a hand valve so that fuel pressure could be accurately controlled. Actual starts made at extremely low delivery pressure, i.e., 4½ psi instead of 12 psi as called for by calibration for ground running. This hand valve was replaced in the late fall of 1948 with an electrically driven valve so that adjustments of fuel line pressure could be carried out at remote control panel.

Appendix II

Thrust Stand Trailer

Since the trailer used was a surplus Army radar antenna trailer, which would probably be unavailable to any other group building such a unit, this section will be devoted to describing the major features originally incorporated and the modifications required, plus some observations based on the experience gained with this unit, rather than the details of dimensions and materials.

The decision to mount the whole JB-2 assembly less wings on a thrust stand rather than the engine alone was based on two principal arguments. The first was that the extra mass of the unit would reduce the excursion of the stand and would aid in damping the oscillations due to intermittent combustion. The second was that the work involved in setting up the engine to operate without the built in equipment was felt at the time to be excessive.

As shown in Figure 5 the engine was supported at front and rear by hanging links which were pivoted in two pyramidal frames at each end of the engine. The front links were fastened to the wing spar, the rear to a reinforced section under the battery box. All pivot points were ball or roller bearings to reduce friction to the minimum. It was decided that while the bomb was in transit, the whole unit should be removed from the thrust stand assembly and locked in a cradle.

Appendix III

Instrument Trailer

A Hoil radar trailer 22' long was converted by raising the roof to give a 6'3" clearance. The interior was then partitioned into three rooms: (1) The control room which had a Herculite window 4' x 2' mounted so as to face the JB-2. (2) The electronics room which had high and low voltage supply for the C.R. tubes, voltage regulators, special DC amplifiers for temperature measurement and the receiving units for the pressure gauges. Also enclosed were eight double beam Dumont 5" blue cathode ray tubes and four 2" timing tubes which were in the field of the four cameras. (3) A photographic dark room so arranged that the camera back opened directly into the room. The entire trailer was air-conditioned by Airgram.

Cameras

The cameras were of the rotating drum type as shown in Figure 10. The lenses were 2" E. F. L. Wollensak Raptars with shutters. Four such lenses were used so that each lens viewed two 5" tubes and one 2" timing tube. The camera drums two on a shaft were driven by a common belt drive whose speed could be controlled by a Variac. Micro-switchs mounted on the drums actuated a solenoid which tripped the lens shutters by wire cable. This system worked well after preliminary adjustments. Figure 11 shows the arrangement of lenses, mirrors and cathode ray tubes.

Pressure Receivers

Three of these were used. They are described in detail in reference No. 4

Temperature Receivers

Three of these were also set up. They are described in detail in reference No. 6

Figure 12 shows the general arrangement of the instrument trailer with reference to the jet and the power trailer.

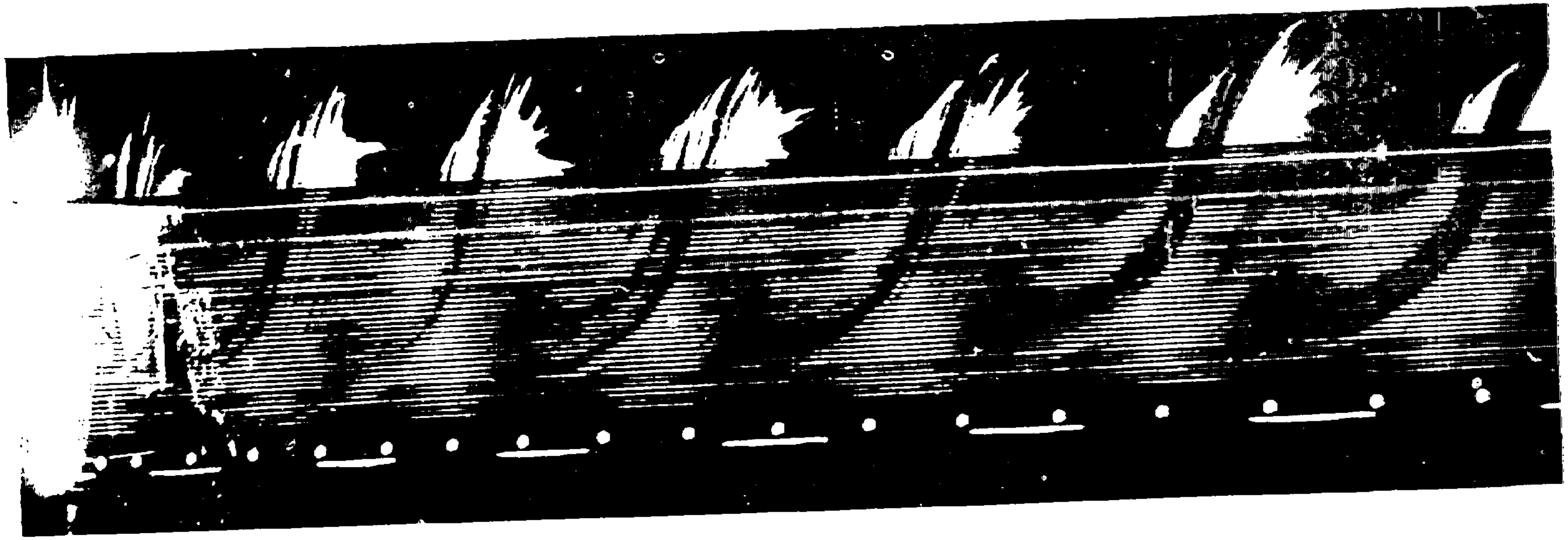


Fig. Ia. Streak photo of full scale pulse jet with $\frac{1}{4}$" holes uncovered.

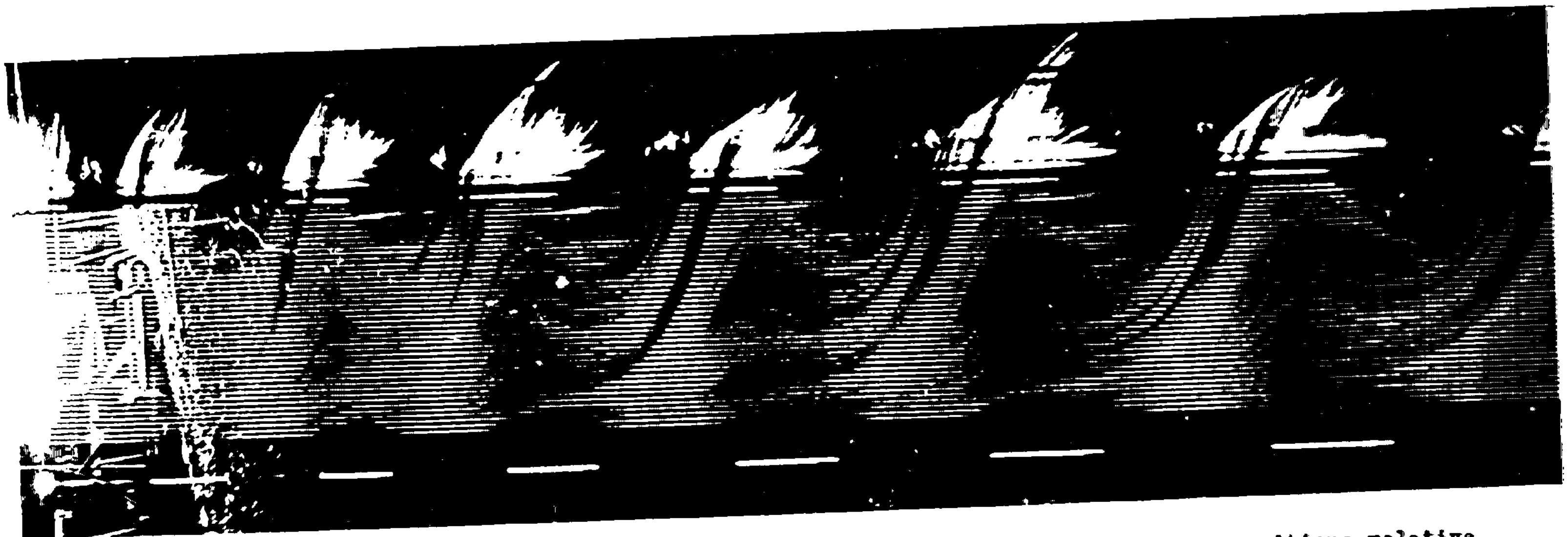
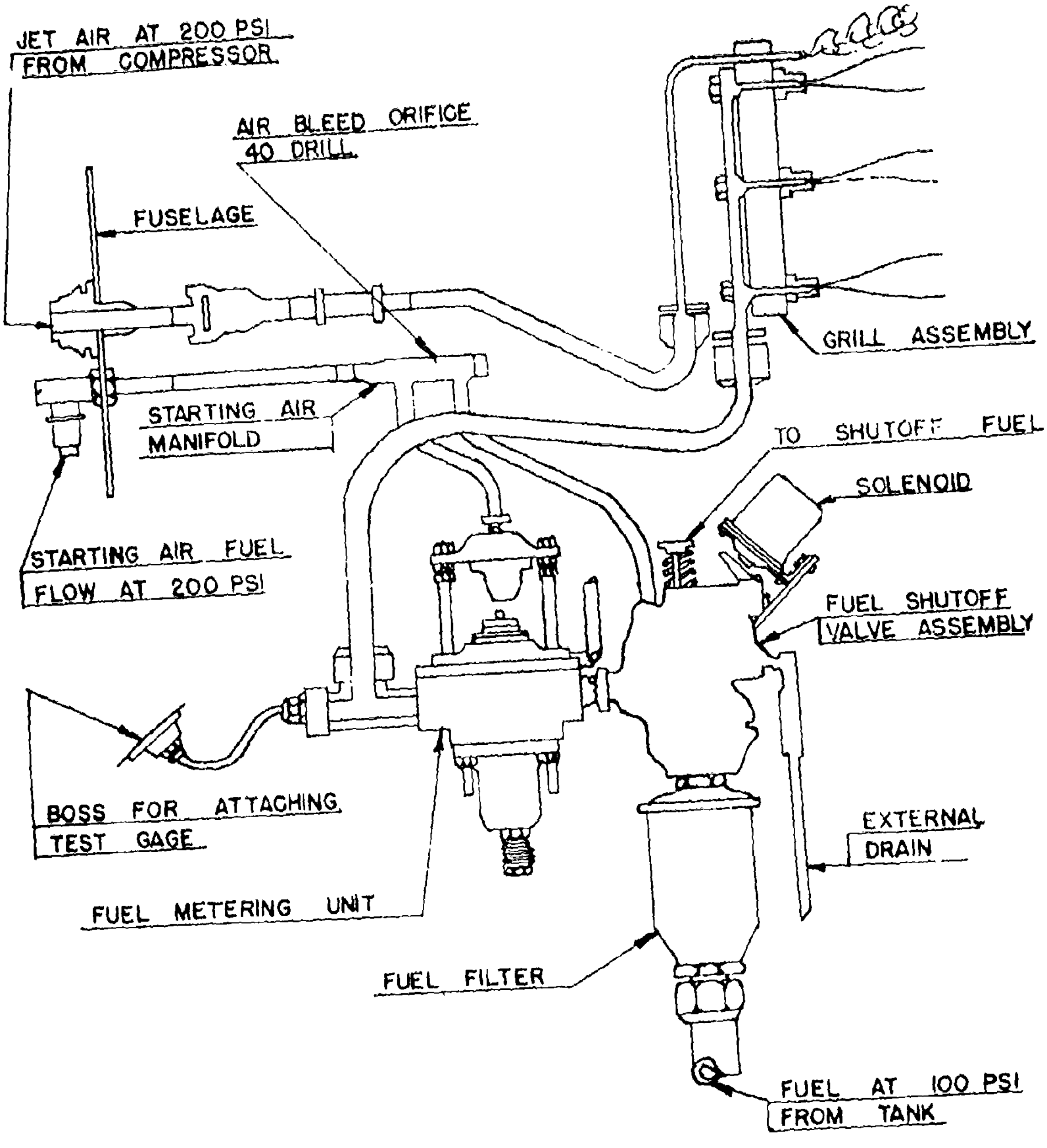


Fig. Ib. Streak photo of full scale pulse jet covered with quartz windows. The valve positions relative to the gas motion are indicated by the white stripes formed by a mirror upstream from the valve bank.

Fig. 2. Tailpipe cycle of JB-2 at 720 frames/sec. The small dots are $\frac{1}{4}$" open windows in the tailpipe.



SCHEMATIC- FUEL METERING SYSTEM

Fig. 3. Modification of fuel metering system to permit purging of combustion chamber through the starting air jets.

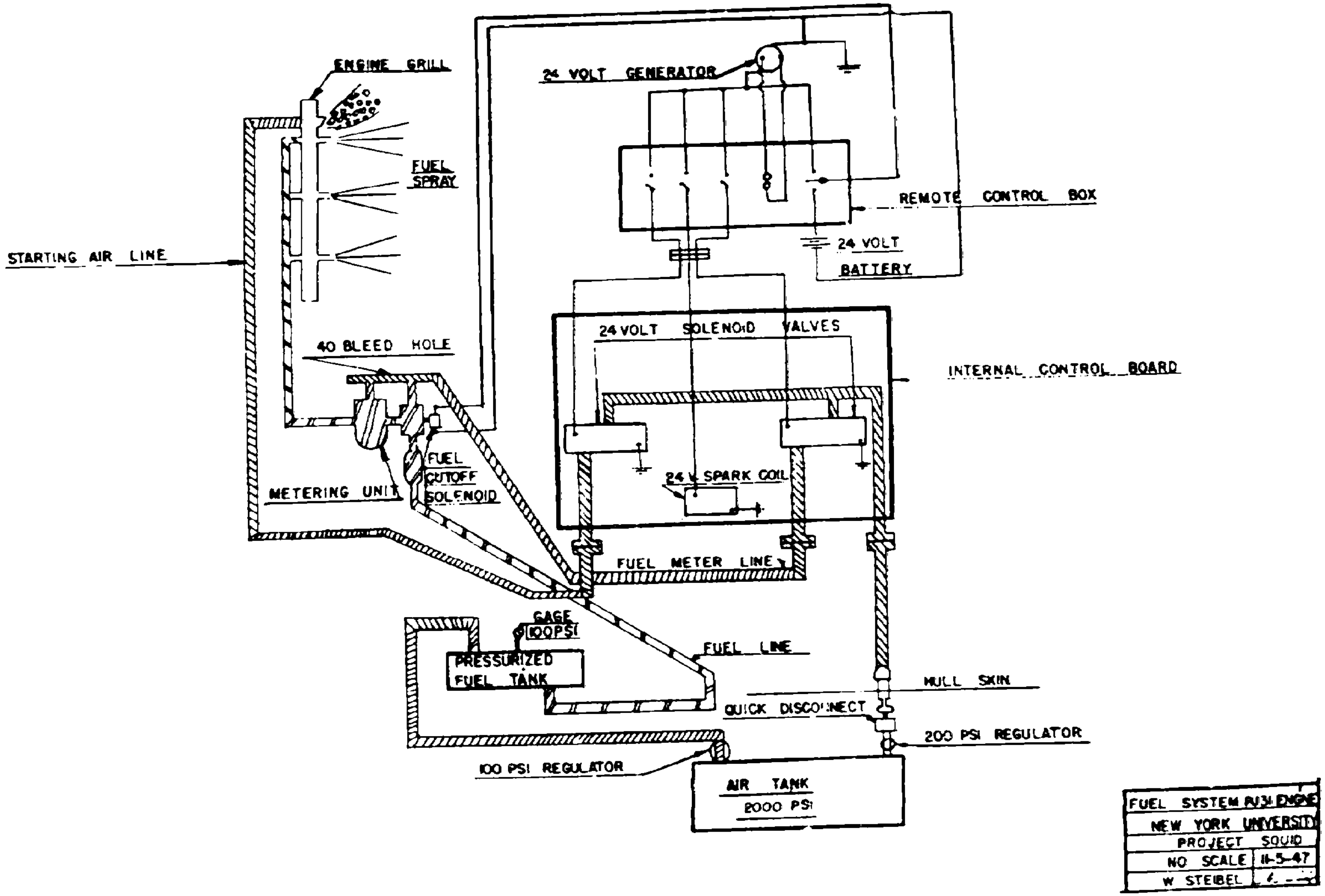


Fig. 4. Modification of fuel system to allow for remote control.

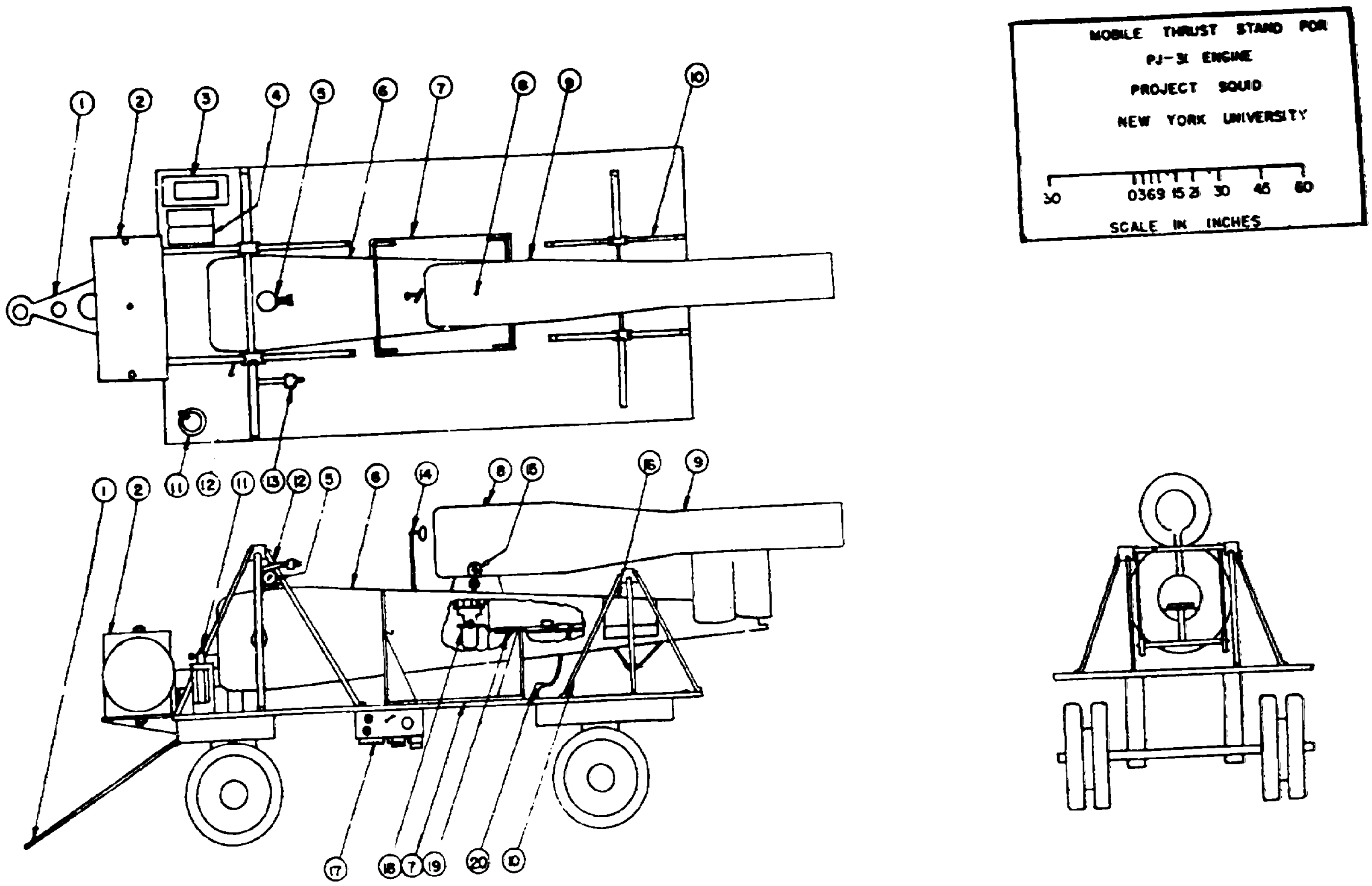


Fig. 5. Mobile thrust stand of A-flame construction.

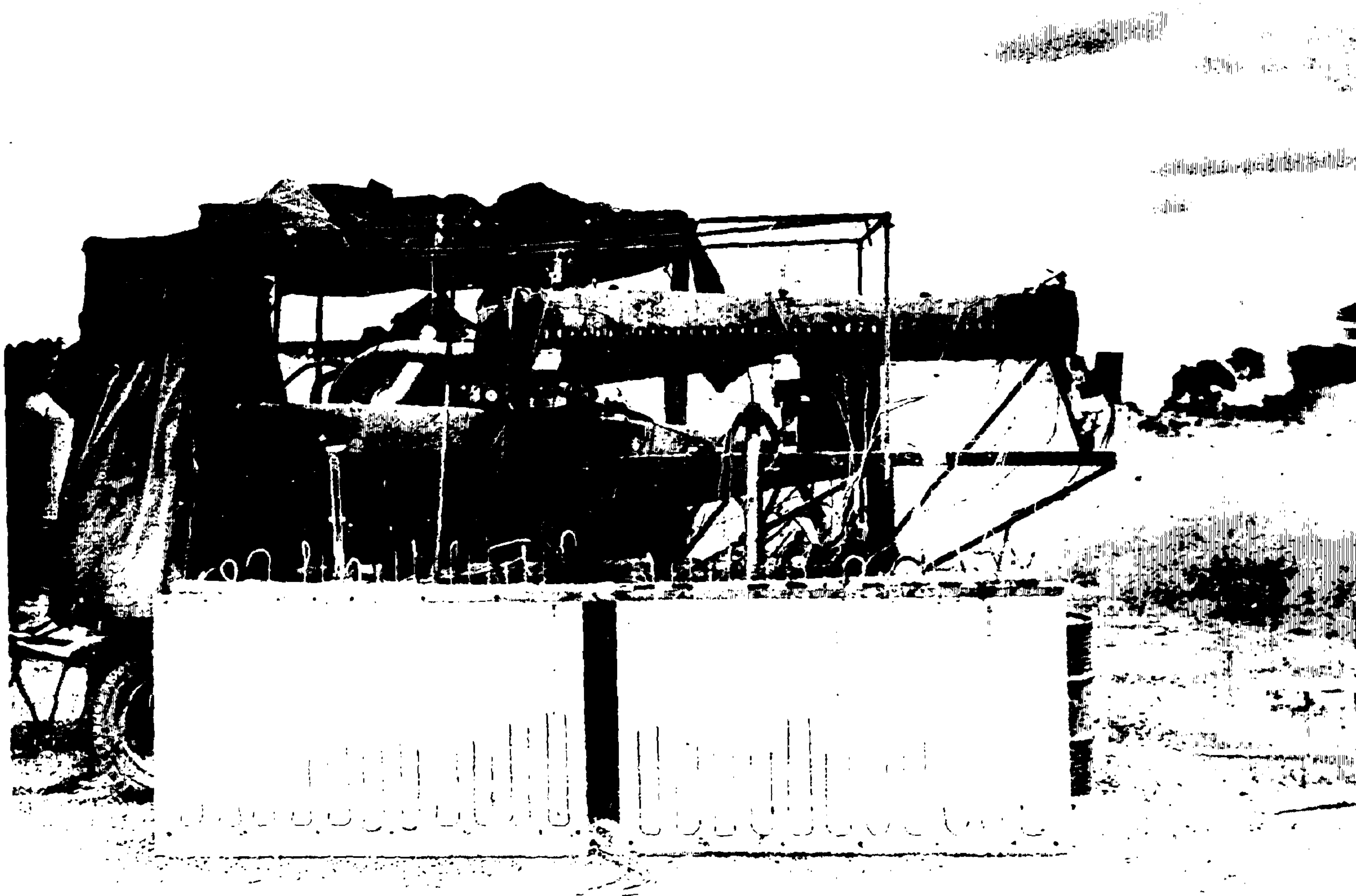


Fig. 6. The JB-2 operating under test. Shown on top are three NYU pressure gauges on the side and three temperature stations mounted at the same axial points. The check manometer system is shown. In the background is the Merlin Engine blower and its 6" supply line.

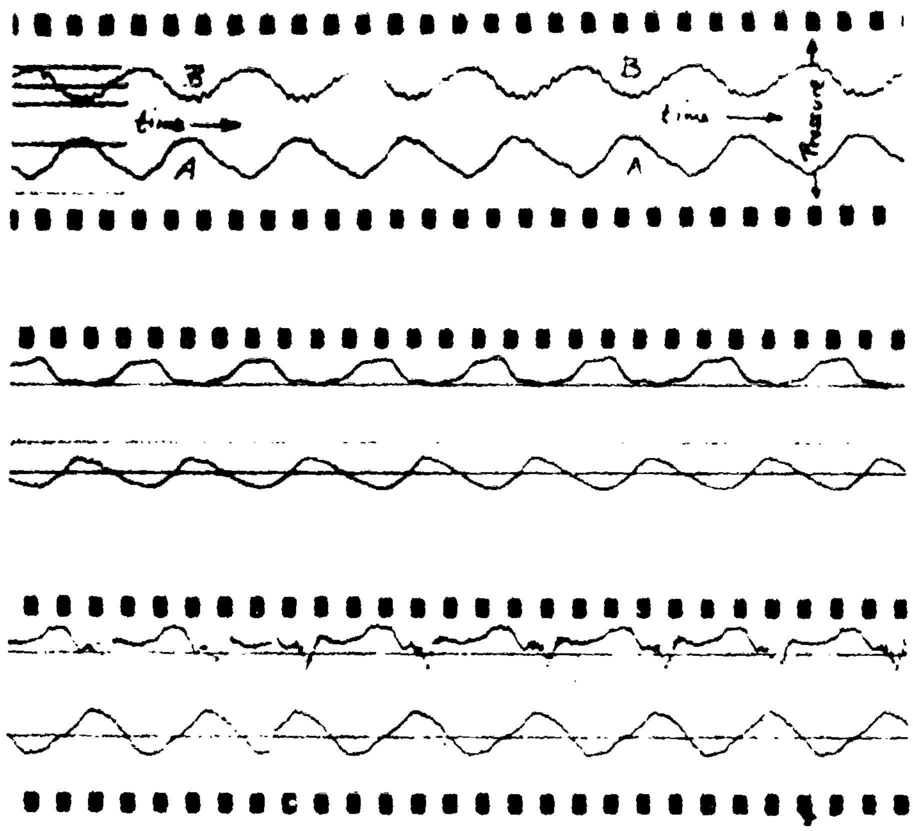


Fig. 7. Pressure traces in a JB-2 run at low throttle. The lower traces in all three figures (A) are combustion chamber traces for reference.

1. Combustion chamber amplitude + 5 to -5 psi.
2. Half way down tailpipe approximately + 4 to -4 psi.
3. Tailpipe + 3 psi plus suspected vibration trace.

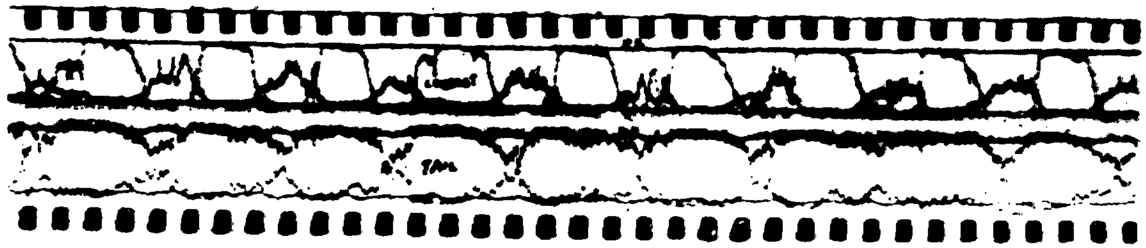


Fig. 8. The upper set of radiation traces were obtained at the combustion chamber. The lower at the tailpipe taken simultaneously.

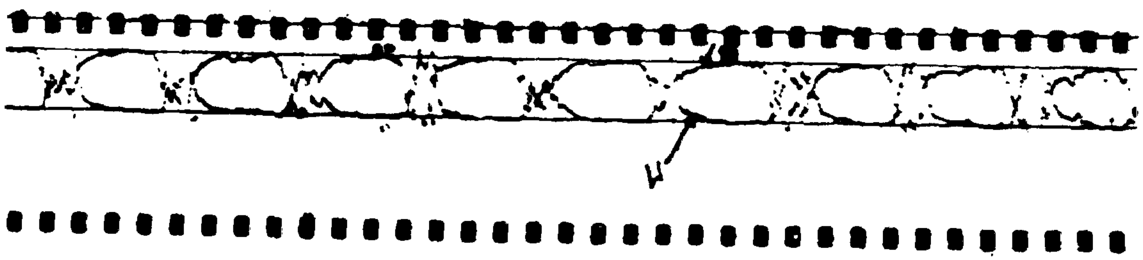


Fig. 9. Combustion chamber trace. The upper trace is from mirror, the lower from the non-mirror or black body channel.

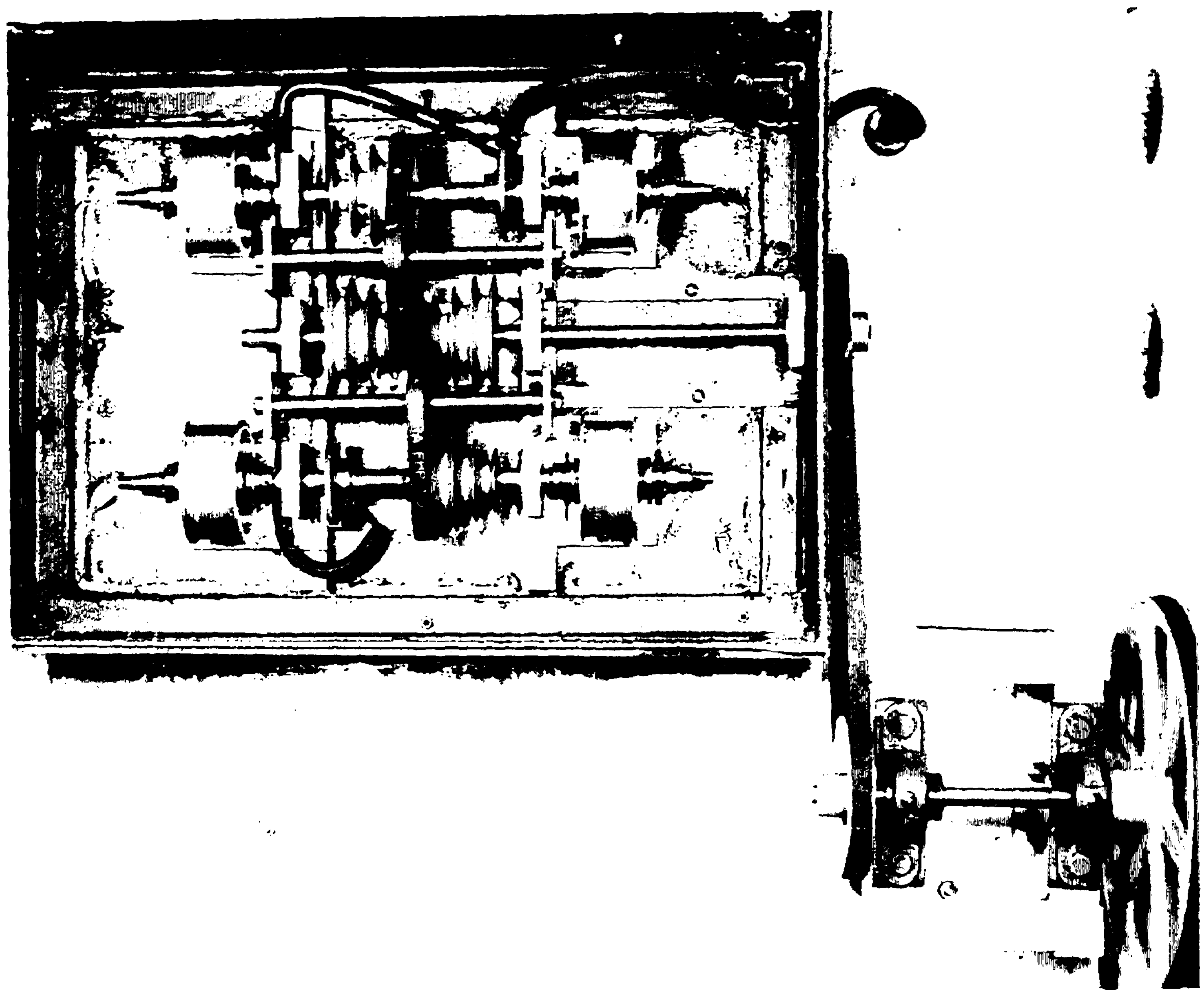


Fig. 10. This belt drive system operated successfully at all times. Microswitches, cam operated were used to trip the shutters to avoid double exposure.

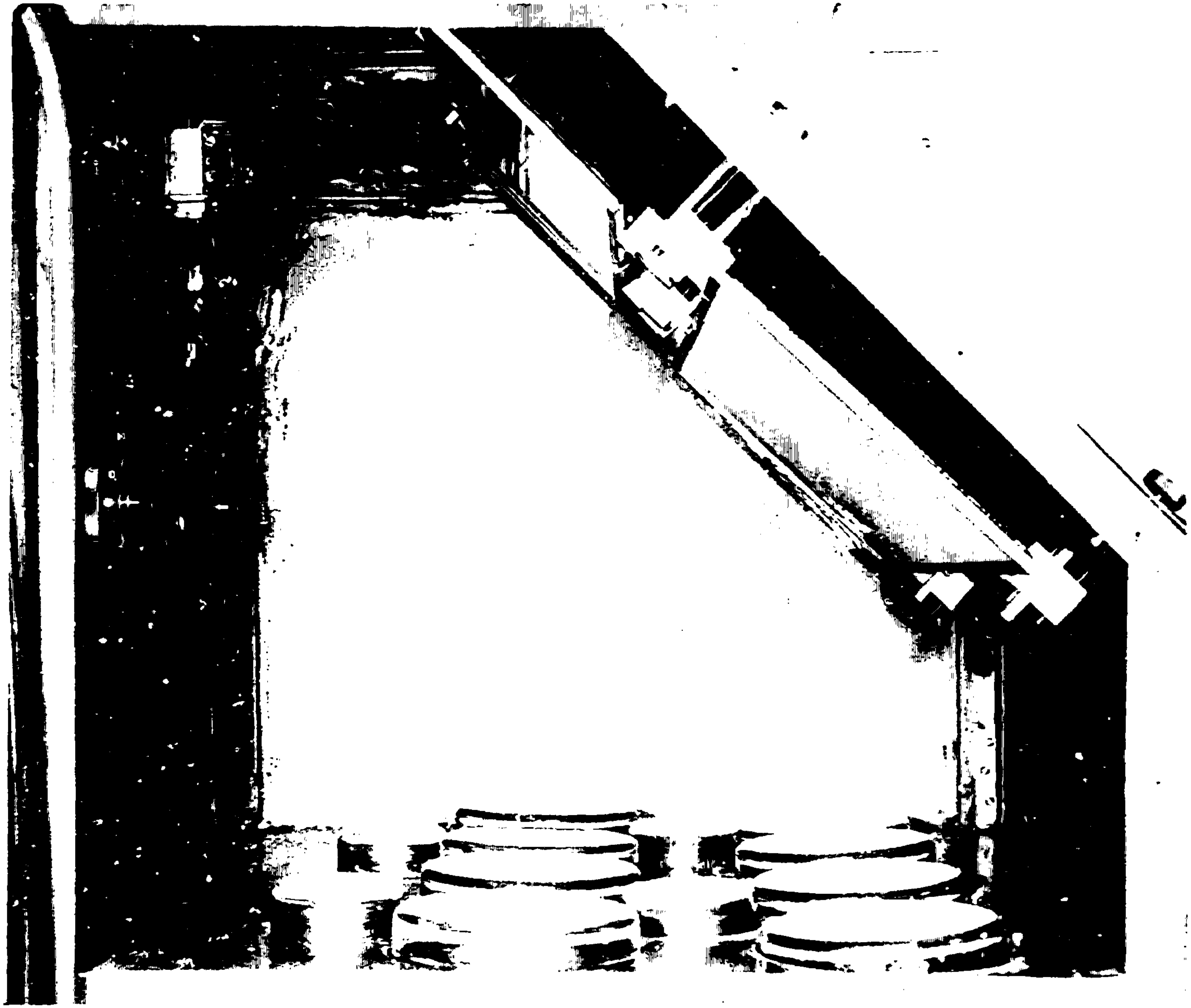


Fig. 11. Shows the lenses, with wire and solenoid trips, the mirrors and arrangement of dual beam and timing tubes.

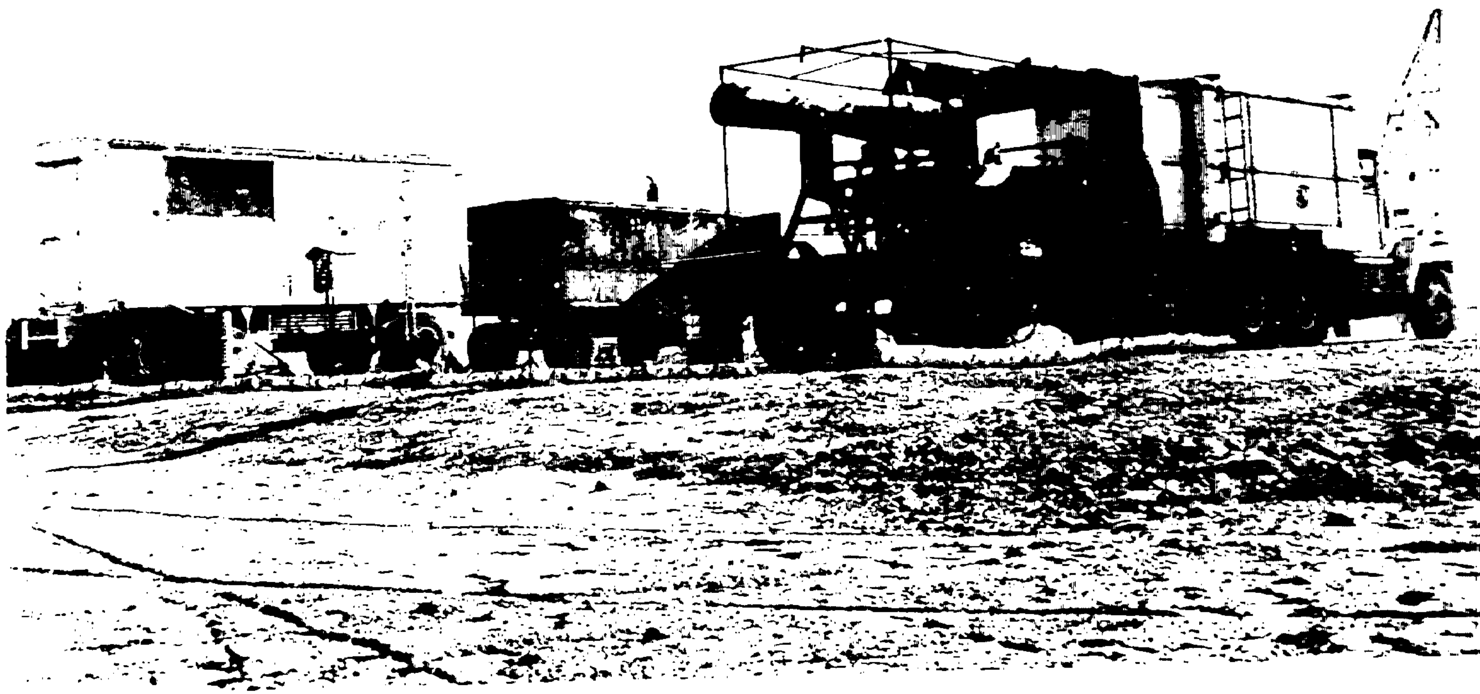


Fig. 12. General arrangement of equipment at Rye Airport. At extreme left the instrument trailer, then the power trailer, the JB-2 and the truck which contained the air compressor. When the Merlin blower was used it was set to the right of the truck.

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58. A. Kuethe, University of Michigan, Ann Arbor, Michigan

59. C. C. Lin, Massachusetts Institute of Technology

60. A. J. Nerad, Research Laboratory, General Electric, Schenectady

61. W. R. Sears, Grad. School of Aero. Engineering, Cornell University

62. J. Keenan, Massachusetts Institute of Technology

63. J. D. Akerman, University of Minnesota

64. W. A. Wildhack, National Bureau of Standards, Washington, D.C.

65. Buffalo-Electro Chemical Corporation, Buffalo, New York

66. D. H. Hill Library, University of North Carolina, Raleigh, North Carolina

67. I.T.E. Circuit Breaker Co., Special Products Div., Philadelphia, Pa.

68. Allison Division, General Motors Corporation, Indianapolis, Indiana

69. B. G. Corporation, New York

70. Fredric Flader, Inc, North Tonowanda, New York

71. General Electric Company, Aircraft Gas Turbines Div., West Lynn, Mass.

72. General Laboratory Associates, Inc., Norwich, New York

73. Stalker Development Company, Bay City, Michigan

74. Stanford University, Stanford, California

75. University of Southern California, Los Angeles, California

76. K. Razak, College of Bus. Admin. and Industry, University of Wichita, Wichita, Kansas

77. Georgia Institute of Technology, Atlanta, Ga. ATTN· Prof. M.J. Goglia
78. Dr.R. B. Dow, BuOrd, Navy Department (Re92)
79. Dr. R. Zirkind, BuAer, Navy Department, Washington, D.C.
80. Dr. A. M. Rothrock, N.A.C.A.
81. Atlantic Research Corporation, 812 N. Fairfax Street, Alexandria, Va.
82. Dr. R. H. Wilhelm, Princeton University
83. J. P. Layton, Princeton University
84. Mark M. Mills, Project SQUID Headquarters, Princeton University
85. J. A. Browning, Thayer School of Engineering, Dartmouth College
86. G. G. Lamb, Northwestern University, Evanston, Illinois
87. A. Ferri, Polytechnic Institute of Brooklyn
88. W. M. Rohsenow, Massachusetts Institute of Technology
89. F. G. Keyes, Massachusetts Institute of Technology
90. E. Johnson, Princeton University
91. H. Hottel, Massachusetts Institute of Technology
92. G. Williams, Massachusetts Institute of Technology
93. Project SQUID Library
94. L. N. K. Boelter, University of California, Los Angeles, California
95. A. Hertzberg, Cornell Aeronautical Laboratory
96. J. Logan, Cornell Aeronautical Laboratory
97. J. Beal, Cornell Aeronautical Laboratory
98. G. Sterbutzel, Cornell Aeronautical Laboratory
99. Office of the Chief of Ordnance, Dept. of the Army, Pentagon, Washington 25, D. C. ATTN· (ORD TB-PS)
100. McCulloch Motors, Inc. 6101 W. Century Blvd. Los Angeles 45, California
101. Dr. G. Akerlof, Chemical Science Bldg., Forrestal Research Center, Princeton University

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REPORT ON FULL SCALE PULSE JET TESTING

New York University

November 7, 1951

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Tests were made of the flame flow pattern in the engine using windows and a strip camera and simultaneous determinations were made of valve position. To measure instantaneous pressures and instantaneous flame temperatures special instruments were developed and mounted on the P. J. 31. Experiments were also made with instantaneous liquid flow meters employing thermistors. Other experiments were performed with pulsating manometer systems. The project ended before simultaneous measures of all parameters could be obtained.

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